CHAPTER 5
BENEFIT/COST ANALYSIS

All the canal-lining alternatives were compared using Benefit/Cost (B/C) analysis. Alternatives with a B/C ratio greater than 1 are economically viable, but alternatives with a B/C ratio less than 1 cannot be justified based on economics. Obviously, the higher the B/C ratio, the better the alternative economically. For instance:

B/C = 10	every dollar invested (cost) returns $10 in benefit
B/C = 1	every dollar invested (cost) returns $1 in benefit
B/C = 0.5	every dollar invested (cost) returns $0.50 in benefit

Benefit—The primary purpose of all the canal-lining alternatives is to conserve irrigation water. Therefore, the primary benefit is the value of the conserved water. For this study, the value of that water is estimated at $50 per acre-foot. District water assessments typically range from $10 to $25 per acre-foot, while water purchased on the open market costs as much as $300 per acre-foot. Secondary benefits are also achieved by canal lining. That is use of adjacent cropland normally flooded by leaking canals and remediation of damage to structures near canals (such as flooded basements) are examples of secondary benefits. However, the value of these secondary benefits is not included in this analysis.

The amount of water conserved by each canal-lining alternative depends on its effectiveness (percent seepage reduction) and the preconstruction seepage rate. For this study, we used a 180-day irrigation season, and a conservative preconstruction seepage rate of 1.0 foot/day (ft^3/ft^2/day). The effectiveness, durability, and maintenance requirements for four generic types of canal linings are listed in table 19.

Cost—The cost of each alternative is calculated as its life-cycle cost ($/ft2-yr). Life-cycle costs are calculated using initial costs, design life (durability), and maintenance costs. Initial costs were taken from tables 2, 3, and 4 in chapter 1 of this report. Durability and Maintenance costs were taken from table 19.

Table 19.—Effectiveness, durability, and maintenance requirements of generic types of canal linings

Type of Lining	Number of Test Sections	Effectiveness (Seepage Reduction)	Durability	Maintenance ($/ft 2-yr)
Concrete	6	70 percent	40-60 years	$0.005
Exposed Geomembrane	14	90 percent	10-25 years	$0.010
Fluid-applied Geomembrane	8	90 percent	10-15 years	$0.010
Concrete with Geomembrane Underliner	3	95 percent	40-60 years	$0.005

Benefit/Cost Ratios—B/C ratios were calculated for each test section and are tabulated in table 20. Sample calculation is shown in appendix E. Many test sections have favorable B/C ratios, and the lining alternatives with the highest B/C ratio include exposed geomembranes, geomembranes with concrete

Table 20.— Benefit/Cost Analysis

Test Section	Const Cost ($/ft2)	Durability Range* (years)	Annualized Const Cost ($/ft2-yr)	Maintenance Cost ($/ft2-yr)	Total Cost ($/ft2-yr)	Effectiveness Seepage Reduction (%)	Benefit/Cost
A-1	2.43	40-60	0.049	0.005	0.054	95	3.7
A-2	2.52	40-60	0.050	0.005	0.055	95	3.6
A-3	1.38	20-30	0.055	0.010	0.065	90	2.9
A-4	1.05	10-15	0.084	0.010	0.094	90	2.0
A-5	1.11	10-15	0.089	0.010	0.099	90	1.9
A-6	1.03	10-15	0.082	0.010	0.092	90	2.0
A-7	2.54	40-60	0.051	0.005	0.056	95	3.5
A-8	1.92	40-60	0.038	0.005	0.043	70	2.9
A-9 & A-10**	1.79						
N-1	4.33	5-15	0.433	0.010	0.443	40	0.2
N-2	3.92	5-15	0.392	0.010	0.402	40	0.2
N-3	2.64	1-5	0.880	0.010	0.890	90	0.2
N-4	2.64	1-5	0.880	0.010	0.890	90	0.2
N-5 Invert	1.74	40-60	0.035	0.005	0.040	40	2.1
N-5	2.00	40-60	0.040	0.005	0.045	70	3.2
N-6	2.20	40-60	0.044	0.005	0.049	70	3.0
N-7	2.14	40-60	0.043	0.005	0.048	70	3.0
N-8	2.14	40-60	0.043	0.005	0.048	70	3.0
N-9	2.07	40-60	0.041	0.005	0.046	70	3.2
T-1	1.70	5-15	0.170	0.010	0.180	40	0.5
T-2	2.16	10-15	0.173	0.010	0.183	90	1.0
T-3	1.40	10-15	0.112	0.010	0.122	90	1.5

* An average of the durability range was used for the B/C analysis

** Removed at District's request - No analysis

Table 20.—Benefit/Cost Analysis - continued

Test Section	Const Cost ($/ft2)	Durability Range* (years)	Annualized Const Cost ($/ft2-yr)	Maintenance Cost ($/ft2-yr)	Total Cost ($/ft2-yr)	Effectiveness Seepage Reduction (%)	Benefit / Cost
O-1a Buried	0.82	20-40	0.027	0.005	0.032	95	6.1
O-1b Buried	0.87	20-40	0.029	0.005	0.034	95	5.8
O-2a Exposed**	0.76						
O-2b Exposed**	0.81						
O-3a	0.84	15-20	0.048	0.010	0.058	90	3.2
O-3b	0.87	15-20	0.050	0.010	0.060	90	3.1
O-4	0.78	10-15	0.062	0.010	0.072	90	2.6
O-5	1.51	20-30	0.060	0.010	0.070	90	2.7
LA-1	1.37	20-30	0.055	0.010	0.065	90	2.9
	1.19	20-30	0.048	0.010	0.058	90	3.2
J-1	1.53	20-30	0.061	0.010	0.071	90	2.6
F-1	0.90	15-20	0.051	0.010	0.061	90	3.0
TF-1	1.43	10-15	0.114	0.010	0.124	90	1.5
LO-1	0.99	15-20	0.057	0.010	0.067	90	2.8
BU-1a	1.26	20-25	0.056	0.010	0.066	90	2.8
BU-1b	1.12		0.050	0.010	0.060	90	3.1
BI-1	0.83	15-20	0.047	0.010	0.057	90	3.3
Underliner	0.54	40-60	0.011	0.000	0.011	25	4.7
Maintenance							
Concrete + GM	0	—	—	0.005	0.005	47.5	19.6
Concrete	0	—	—	0.005	0.005	35	14.5
Exp GM	0	—	—	0.010	0.010	45	9.3
Liquid Applied	0	—	—	0.010	0.010	45	9.3

* An average of the durability range was used for the B/C analysis

** Buried after 2 years - No analysis

cover, and concrete alone. Each of these alternatives has advantages and disadvantages, and is discussed in further detail below. In addition, the B/C ratios of a couple of options are discussed, including installation of the geomembrane underliner component and performing annual maintenance.

Exposed Geomembrane—HDPE (A-3), Hypalon (A-5 and A-6), and Teranap (L-1 and J-1) are types of exposed geomembranes. These exposed geomembranes have favorable B/C ratios in the range of 3.0 to 3.9. They are relatively easy to construct and can be installed by irrigation districts with their own equipment and labor. They can be installed without significant overexcavation and with minimal loss of freeboard. Exposed geomembranes show promise for some special applications such as lining of existing steel flumes (test section F-1). The biggest disadvantage is the risk of mechanical damage (animal traffic, maintenance equipment, vandalism, etc) as well as environmental damage from UV light. Also, exposed geomembranes can have uplift problems if not ballasted in the invert. High velocities seem to compound uplift problems. Finally, exposed geomembranes are often poorly maintained because of the district's lack of experience with these materials, and the special equipment sometimes needed for repairs (such as an extrusion welder for HDPE and PP).

Concrete alone—RCC with shotcrete side slopes (N-5), shotcrete alone (N-6, N-7, N-8 and N-9), and grout-filled mattress (A-8) are examples of how concrete can be used alone. These concrete liners have favorable B/C ratios ranging from 3.0 to 3.2. Concrete provides a hard durable surface that is resistant to mechanical damage. District personnel are familiar with concrete and can easily perform the required maintenance. The only disadvantage is that concrete cracks over time, and the long-term effectiveness is only about 70 percent.

Geomembrane with Concrete Cover—A variety of geomembranes and concrete covers, including shotcrete over PE (A-1), shotcrete over PVC (A-2), and grout-filled mattress over PVC (A-7), are found in their group. These lining alternatives have favorable B/C ratios ranging from 3.5 to 3.7. These linings offer the highest effectiveness (95 percent) because the geomembrane provides the water barrier and the concrete protects the geomembrane from mechanical damage and weathering. Maintenance requirements are virtually identical to concrete alone.

Geomembrane Lining of Steel Flumes—Liquid Boot (T-3) and PP (F-1) are in this group. These lining alternatives for existing steel flumes have favorable B/C ratios ranging from 1.8 to 2.7. The PP alternative is an exposed geomembrane and may be difficult to maintain because of the need for an extrusion welder for patching. Liquid Boot is the only spray-applied membrane that is still in service. Steel flumes may be a specialty niche for this type of product. Surface preparation by sandblasting of the steel flume (T-2) has not proven cost effective because the expensive sandblasting did not improve performance over brooming (T-3).

Spray-applied Geomembranes—This group includes sprayed-in-place foam (N-1 and N-2), coated geotextile (N-3 and N-4), and Liquid Boot over existing concrete. These spray-applied membranes have unfavorable B/C ratios ranging from 0.2 to 0.5. Problems with field fabrication of these spray-applied membranes make them a poor choice except, perhaps, for special applications such as lining of existing steel flumes as discussed above.

Geomembrane Underliner—B/C analysis allows for the evaluation of some of the individual components of a lining alternative. The addition of the geomembrane underliner to a concrete liner has a favorable B/C ratio of about 4.8, showing that the small additional one-time cost of the geomembrane yields big benefits by raising the effectiveness from 70 percent up to 95 percent.

Buried GCL—This study suggests that buried GCL's have very favorable benefit-cost ratios of about 6; however, these results are very preliminary as the GCL's have only been in service about 2 years. Also, the GCL is the only buried geomembrane included in this study and the reported costs might not be directly comparable to exposed geomembranes and geomembranes with concrete cover. Specifically, costs associated with over-excavation and flatter side-slopes have not been included for the buried GCL test sections.

Maintenance—During the 10-year study period, the maintenance requirements of all the alternatives have been quite low (\$0.005 to \$0.010 per ft^2/year). However, this small amount of annual maintenance has a large effect on durability and effectiveness. This study suggests that annual maintenance can double the service life of all the alternatives. B/C analysis shows that every dollar spent on maintenance can return \$10 to \$20 in conserved water. The benefits of annual maintenance cannot be overstressed!

Sensitivity Analysis—The B/C ratios are estimates based on numerous assumptions and input parameters. The B/C ratios are directly proportional to the value of conserved water, effectiveness, durability, and preconstruction seepage rates and inversely proportional to construction costs. Therefore, changes in any of these parameters would cause proportional changes in all the alternatives but would not change any of their relative positions. Maintenance costs have been low for all the alternatives and therefore have minimal effect.